Dynamic Data Driven Applications Systems (DDDAS)

Integrity ★ Service ★ Excellence

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Report Documentation Page

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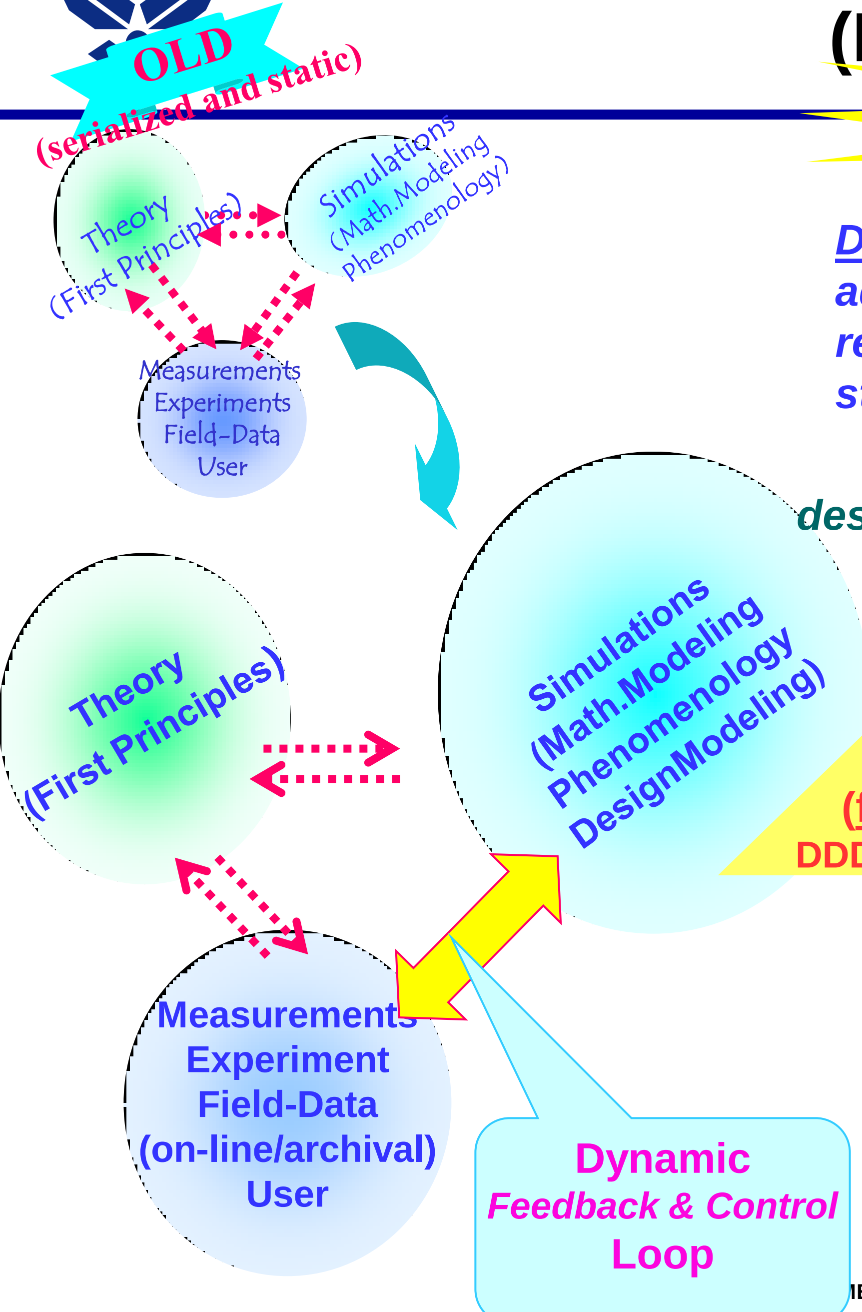
PROGRAM NAME: Dynamic Data Driven Applications Systems (DDDAS)

BRIEF DESCRIPTION OF PORTFOLIO:
Advanced methods for applications modeling/simulation and instrumentation (sensoring/control); dynamic/adaptive runtime supporting integrated computational environments spanning and unifying the high-end with the real-time data acquisition and control

LIST SUB-AREAS IN PORTFOLIO:
- **Application Modeling/Simulation**
- **Application Algorithms**
- **Systems Software**
- **Instrumentation methods**

- **New Program – announced in AFSOR BAA-2011 (posted in Spring2011)**
- **Projects awarded in 4QFY11**

Dynamic Data Driven Applications Systems (DDDAS)



InfoSymbiotic Systems

***DDDAS**: ability to dynamically incorporate additional data into an executing application, and in reverse, ability of an application to dynamically steer the measurement process*

a "revolutionary" concept enabling to design, build, manage, understand complex systems

Dynamic Integration of
Computation & Measurements/Data
Unification of
Computing Platforms & Sensors/Instruments
(from the High-End to the Real-Time, to the PDA)
DDDAS – architecting & adaptive mngmnt of sensor systems

***Challenges*:**
Application Simulations Methods
Algorithmic Stability
Measurement/Instrumentation Methods
Computing Systems Software Support

Synergistic, Multidisciplinary Research

Advances in Capabilities through DDDAS

- **DDDAS: integration of application simulation/models with the application instrumentation components in a dynamic feed-back control loop**
  - ➢ **speedup of the simulation, by replacing computation with data in specific parts of the phase-space of the application**

    and/or
  - ➢ **augment model with actual data to improve accuracy of the model, improve analysis/prediction capabilities of application models**
  - ➢ **dynamically manage/schedule/architect heterogeneous resources, such as:**
  - ▪ **networks of heterogeneous sensors, or networks of heterogeneous controllers**
  - ➢ **enable ~decision-support capabilities w simulation-modeling accuracy**
- **unification from the high-end to the real-time data acquisition and control**

DDDAS /InfoSymbiotics

is the unifying paradigm

Fundamental Science and Technology Challenges for Enabling DDDAS Capabilities

- **Application modeling (in the context of dynamic data inputs)**
  - **interfacing applications with measurement systems**
  - **dynamically invoke/select appropriate application components**

    multi-modal, multi-scale – dynamically invoke multiple scales/modalities
  - **switching to different algorithms/components depending on streamed data**

    dynamic hierarchical decomposition (computational platform **-** sensor) and partitioning
- **Algorithms**
  - **tolerant to perturbations of dynamic input data**
  - **handling data uncertainties, uncertainty propagation, quantification**
- **Measurements**
  - **multiple modalities, space/time-distributed, heterogeneous data management**
- **Systems supporting such dynamic environments**
  - **dynamic execution support on heterogeneous environments**
    - new fundamental advances in compilers (runtime-compiler)
    - integrated architectural frameworks of cyberifrastructure encompassing app-sw-hw layers
  - **extended spectrum of platforms (*beyond traditional computational grids*)**

    grids of: sensor networks and computational platforms
  - **architect and manage heterogeneous/distributed sensor networks**

DDDAS environments entail new capabilities but also new requirements and environments

… beyond GRID Computing -> SuperGrids

and… beyond the (traditional) Clouds

What makes DDDAS(*InfoSymbiotics*) TIMELY NOW MORE THAN EVER?

- **Emerging scientific and technological trends/advances**
  - ***ever more complex applications – systems-of-systems***
  - **increased emphasis in complex applications modeling**
  - **increased computational capabilities (multicores)**
  - **increased bandwidths for streaming data**
  - **Sensors– Sensors EVERYWHERE… *(data intensive Wave #2)***
    - ***Swimming in sensors and drowning in data*** **- LtGen Deptula (2010)**

    Analogous experience from the past:

    - ***"The attack of the killer micros(*microprocs*)"*** **- Dr. Eugene Brooks, LLNL (early 90's)**

      about microprocessor-based high-end parallel systems

      then seen as a problem – have now become an opportunity for advanced capabilities

    Back to the present and looking to the future:

    - ***"Ubiquitous Sensoring – the attack of the killer micros(*sensors*) – wave # 2"***

      Dr. Frederica Darema, AFOSR (2011, LNCC)

      <u>challenge</u>: how to deal with heterogeneity, dynamicity, large numbers of such resources

      <u>opportunity</u>: "smarter systems" – InfoSymbiotics DDDAS is the way to achieve such capabilities

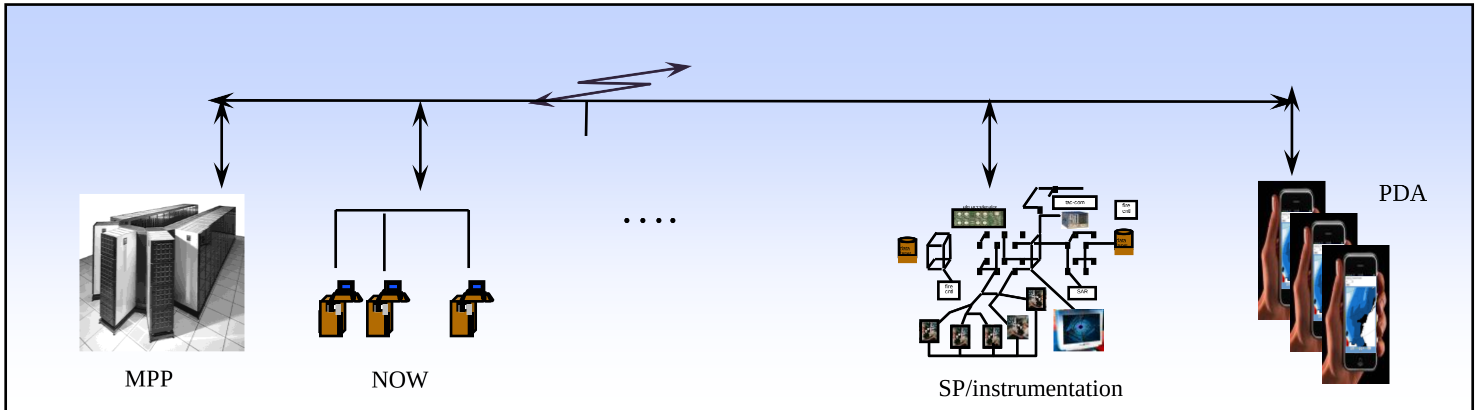
- **Need capabilities for adaptive management of such resources**
  - **advances made thus far, can be furthered in an accelerating way**

Multicore-based Systems (InfoGrids)
(Multicores everywhere!)

Multicores in High-End Platforms
- Multiple levels of hierarchies of processing nodes, memories, interconnects, latencies

Multicores in "measurement/data" Systems
- Instruments, Sensors, Controllers, Networks, …

Multiple levels of muticores



DDDAS - Integrated/Unified Application Platforms

Adaptable Computing and Data Systems Infrastructure
spanning the high-end to real-time data-acquisition & control systems
manifesting heterogeneous multilevel distributed parallelism
system architectures – software architectures

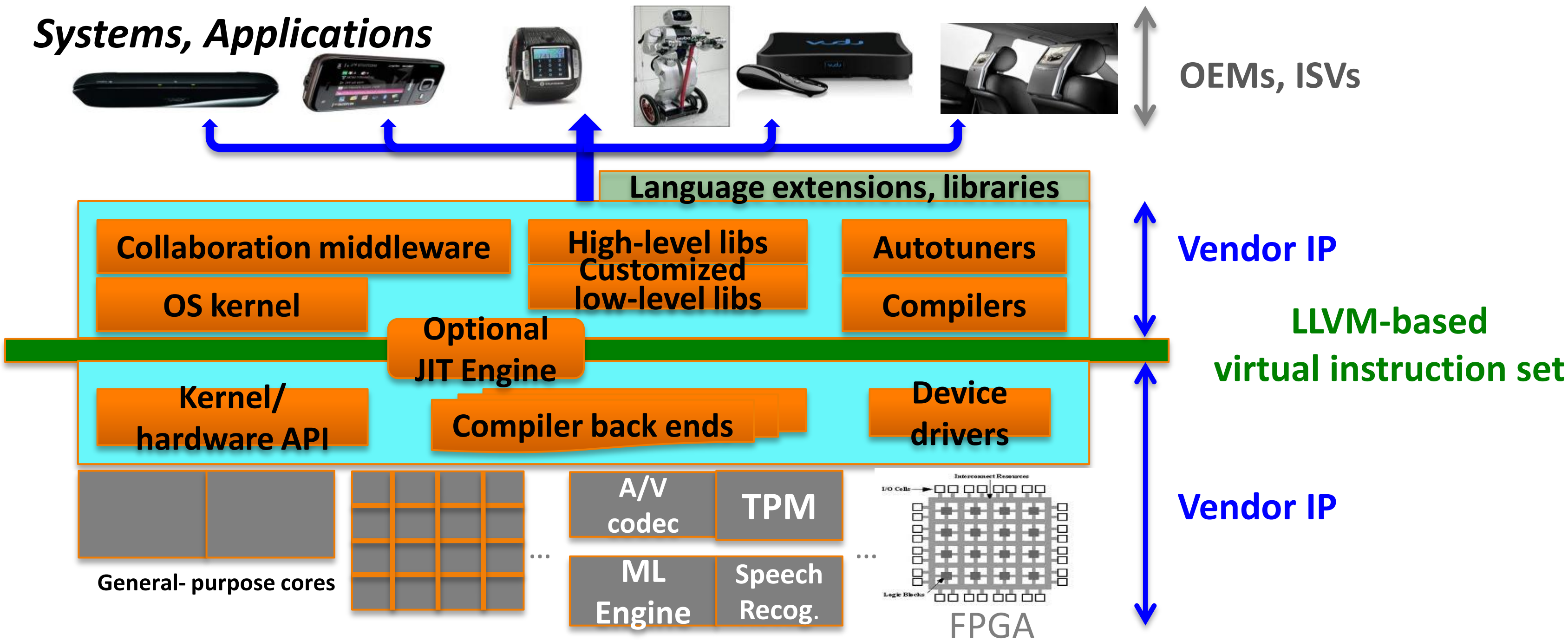
Fundamental Research Challenges in Applications- and Systems-Software
- Map the multilevel parallelism in applications to the platforms multilevel parallelism and for multi-level heterogeneity and dynamic resource availability
- Programming models and environments, new compiler/runtime technology for adaptive mapping
- Adaptively compositional software at all levels (applications/algorithms/ systems-software
- "performance-engineering" systems and their environments

SuperGrids: Dynamically Coupled Networks of Data and Computations

Example of Runtime-Compiler effort I started in ~2000 (NGS Program)

Programming Heterogeneous Systems

LLVM: Compiler Infrastructure for compile-, link-, run-time , iterative program optimization



LLVM in the Real World Today

Major companies using LLVM: Adobe, AMD, Apple, ARM, Cray, Intel, Google, Nokia, nVidia, Qualcomm, Sony

- **MacOS X 10.7, iOS 5: LLVM is the primary compiler on both platforms, <u>replacing GCC</u>**
  Nearly all MacOS 10.7 application software compiled with LLVM
- **OpenCL: <u>*All*</u> known commercial implementations based on LLVM**
  AMD, Apple, ARM, Intel, nVidia, Qualcomm
- **HPC: Cray using LLVM for Opteron back-ends, e.g., in Jaguar (ORNL)**
  New Sandia Exascale project using LLVM as compiler system

Where we are … & QUO VADIMUS

**We have been building advances over the last few years…
programming environments and runtime support for
complex, distributed, heterogeneous systems**

Agency Programs (past and present)

DARPA
- Systems - Performance Engineering

NSF
- Next Generation Software Program
  and successor programs
  - Advanced Execution Systems
  - Performance Engineering Systems
  - Cross-Systems Integration
- Dynamic Data Driven Applications Systems

DOE/ASCR
- SciDAC, and Math and CS Programs
  (Computational Sciences - CS+Applications

AFOSR – Recent/2011 BAA
- Dynamic Data Driven Applications Systems

+…
- expected collaboration w other AFOSR Programs
  and other agencies

Synergistic, Multidisciplinary Research
across sub-areas in Computer Sciences
&
across CS and domain
sciences/engineering
(Computational Sciences)

- Systems Performance Modeling
- Dynamic Runtime Support
  (Runtime Compiler System - RCS)
- Application Composition Systems
- Applications modeling
- Instrumentation Adaptive Management

Applications Modeling
Math&Stat Algorithms
Systems Software
Instrumentation/Control Systems

Impact of prior DDDAS Efforts – Multidisciplinary & NSF-led /Multiagency (Examples of Areas of DDDAS Impact)

- **Physical, Chemical, Biological, Engineering Systems**
  - **Materials, system health monitoring, molecular bionetworks, protein folding.. chemical pollution transport (atmosphere, aquatic, subsurface), ecological systems, …**
- **Medical and Health Systems**
  - **MRI imaging, cancer treatment, seizure control**
- **Environmental (prevention, mitigation, and response)**
  - **Earthquakes, hurricanes, tornados, wildfires, floods, landslides, tsunamis, …**
- **Critical Infrastructure systems**
  - **Electric-powergrid systems, water supply systems, transportation networks and vehicles (air, ground, underwater, space), …**

  condition monitoring, prevention, mitigation of adverse effects, ..
- **Homeland Security, … ications, Manufactu…**
  - **Large-Scale Con… …onments**

"revolutionary" concept enabling to design, build, manage and understand complex systems

NSF/ENG Blue Ribbon Panel (Report 2006 – Tinsley Oden)

List of Projects/Papers/Workshops in www.cise.nsf.gov/dddas, www.dddas.org

(+ recent/August2010 MultiAgency InfoSymbtiotics/DDDAS Workshop)

The AirForce 10yr + 10 Yr Outlook:

Technology Horizons Report

Top Key Technology Areas

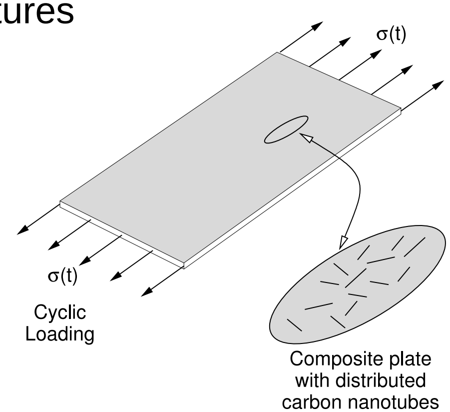
- Autonomous systems
- Autonomous reasoning and learning
- Resilient autonomy
- Complex adaptive systems
- V&V for complex adaptive systems
- Collaborative/cooperative control
- Autonomous mission planning
- Cold-atom INS
- Chip-scale atomic clocks
- Ad hoc networks
- Polymorphic networks
- Agile networks
- Laser communications
- Frequency-agile RF systems
- Spectral mutability
- Dynamic spectrum access
- Quantum key distribution
- Multi-scale simulation technologies
- Coupled multi-physics simulations
- Embedded diagnostics
- Decision support tools
- Automated software generation
- Sensor-based processing
- Behavior prediction and anticipation
- Cognitive modeling
- Cognitive performance augmentation
- Human-machine interfaces

Examples of Projects from DDDAS/AFOSR BAA
(awarded 4QFY11)

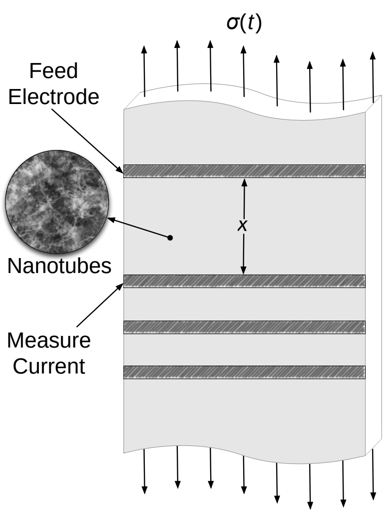
Development of a Stochastic Dynamic Data-Driven System for Prediction of Material Damage

J.T. Oden (PI), P. Bauman, E. Prudencio, S. Prudhomme, K. Ravi-Chandar - UTAustin

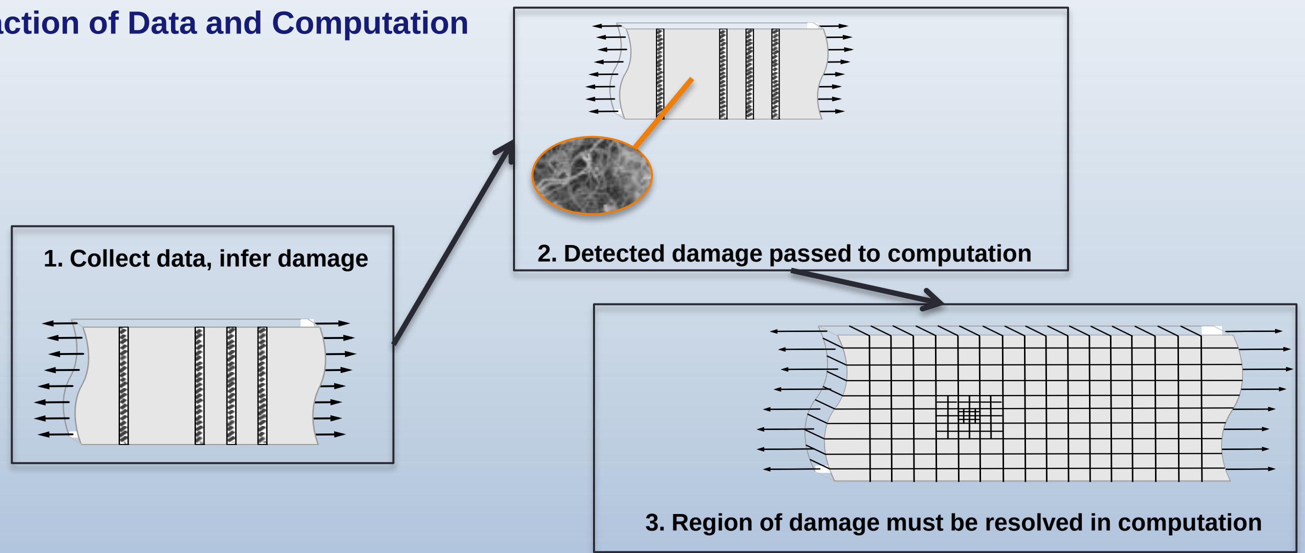
- **Goal**: Dynamic Detection and Control of Damage in Complex Composite Structures



- **Approach and Objectives:**
  - **Coupled simulation and sensoring&control**
  - **Advanced methods of detecting potential or onset of damage**
  - **Damage evolution dynamically controlled by "limited load amplitude"**
- **Methodology:**
  - **Simulations based on a family of continuum damage models**
  - **Cyclic loading of composite plates with a distributed system of carbon nano-particle sensors**
  - **Dynamic calibration and model selection based on Bayesian methods driven by sensor data**



Interaction of Data and Computation

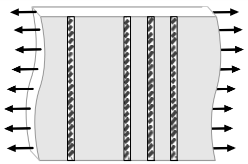


Development of a Stochastic Dynamic Data-Driven System for Prediction of Material Damage

J.T. Oden (PI), P. Bauman, E. Prudencio, S. Prudhomme, K. Ravi-Chandar - UTAustin

- **Features of Approach**
  - **Models based on continuum damage mechanics theories (e.g. Lemaitre and Chaboche)**
  - **Experiments done on fiber-reinforced composite plates enriched with distributed carbon nano-tubes acting as sensors of material stiffness loss**
  - **Experimentally observed data and parameters will be used in Bayesian-based model selection algorithms**
  - **Actual tests up to fatigue failure will determine the effectiveness of variants of approach**

- **Experimental Testbed:**
  Damage Generation and Detection
  - **Specimen: fiber composite with embedded carbon nanotubes (by Designed Nanotubes, Austin, TX)**
  - **Mechanical load profile:**
    - **Quasi-static, but time dependent (ramp, load cycling, creep)**
    - **Cyclic loading of composite plates with a distributed system of carbon nano-particle sensors**
  - **Mechanical measurement: Digital image correlation to find spatial variation of strain**
  - **Electrical measurement: Current measured at different locations, load levels, and times**



1. Load specimen, collect data:

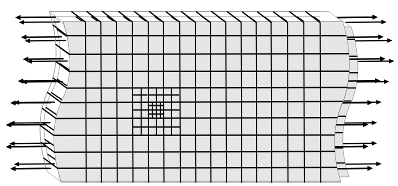
$j(x), \epsilon(x)$

Resistance inferred from current

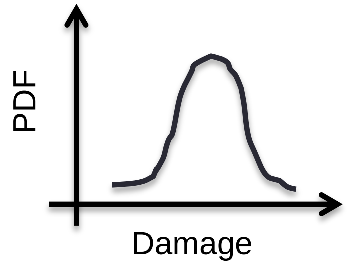
2. Infer damage field from resistance, strain using Bayesian statistical inverse problem

$$\pi(m|d) \propto \pi(m)\pi(d|m)$$

3. Use damage field to infer parameters of damage model



4. Propagate uncertain Parameters to produce PDF of damage

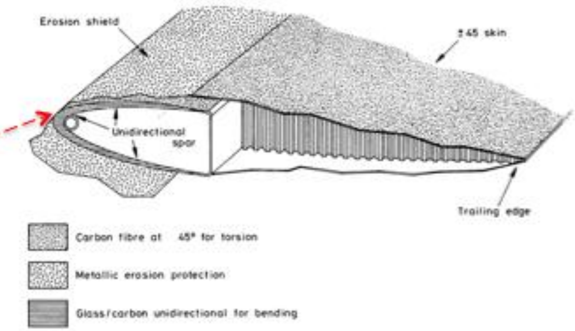


Advanced Simulation, Optimization, and Health Monitoring of Large Scale Structural Systems

Y. Bazilevs, A.L. Marsden, F. Lanza di Scalea, A. Majumdar, and M. Tatineni (UCSD)

- **Main Objective:**
  A Computational Steering Framework for Large-Scale Composite Structures & Environment-coupled, based on Continually and Dynamically Injected Sensor Data

- **Key Features:**
  - **A structural health monitoring (SHM) system**
  - **Simulation model of a structural system with fluid-structure interaction (FSI)**
  - **Sensitivity analysis, optimization and control software module**
  - **Implementation framework in high-performance computing (HPC) environments**
  - **Integration of FSI, SHM, sensitivity analysis, optimization, control, and HPC into a unified DDDAS framework**

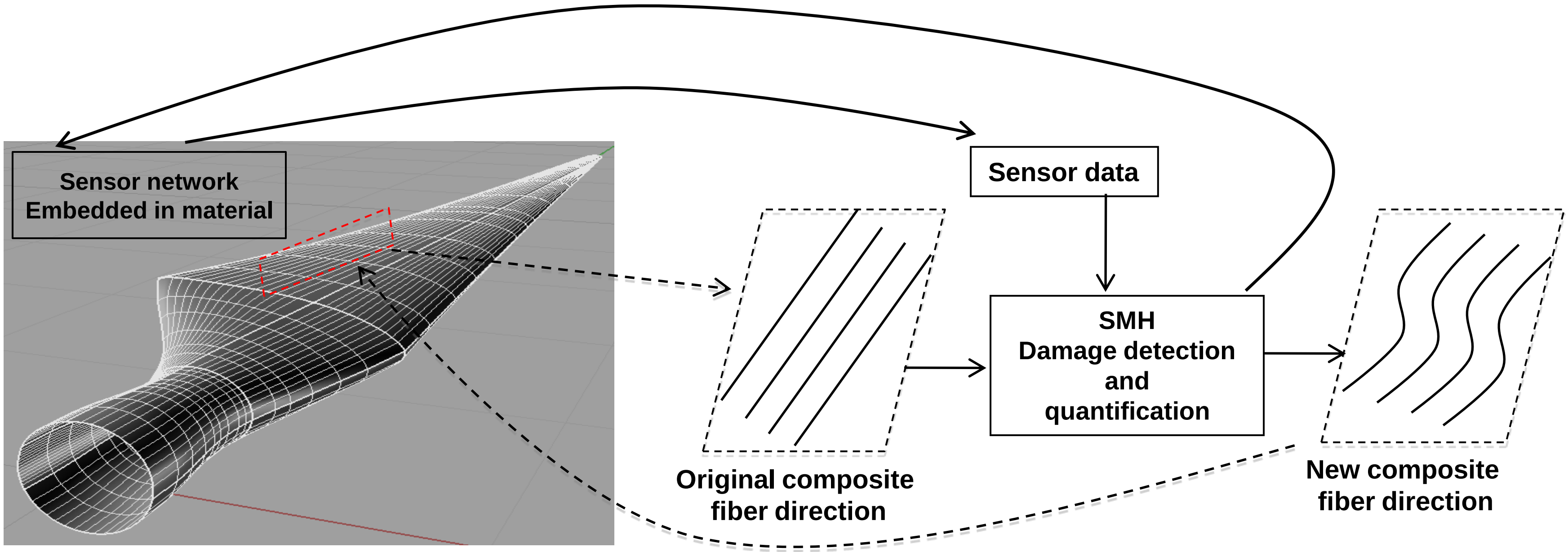


Advanced Simulation Model:
1. Simulate full-scale, 3D, time-dependent FSI
2. Use a structural model with built-in damage from SHM data

Structural Health Monitoring:
1. Structural damage detection and quantification
2. Assessment of the remaining fatigue life of the structure

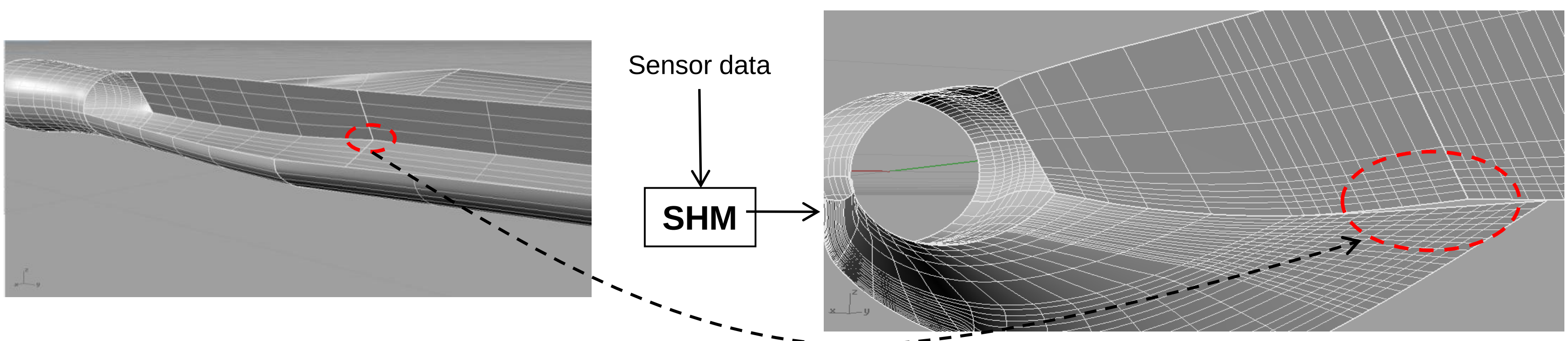
Sensitivity analysis, optimization and control:
1. Assess the sensitivity of the quantities of interest due to uncertainty in input damage parameters.
2. Optimize structure operating conditions to minimize further damage and increase structure remaining fatigue life

Example Case 1: DDDAS Loop for Detected In-plane Waviness



Re-compute constitutive matrix and update structural model ***on the fly!***

Example Case 2: DDDAS Loop for Shear-Web-to-Skin Adhesive Disbond



Introduce disbond by disconnecting structural patches

Advanced Simulation, Optimization, and Health Monitoring of Large Scale Structural Systems

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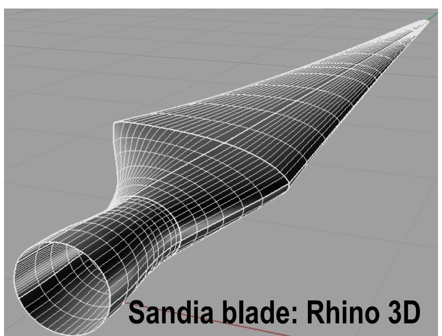
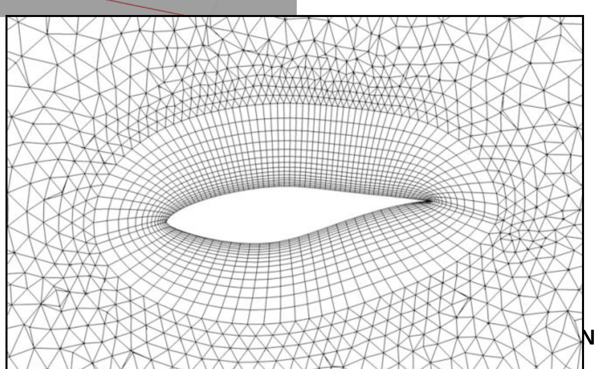
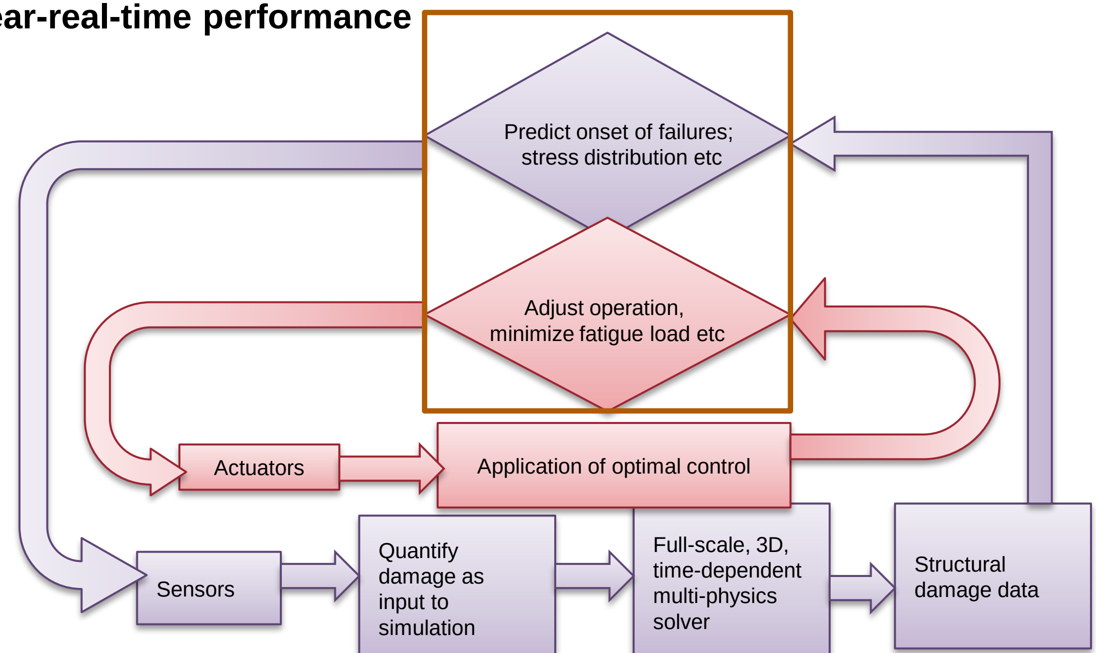
- **Methodology:**
  - **advanced simulation models encompassing time-dependent complex geometry, and non-linear material behavior producing high-fidelity outputs (stress distributions)**
  - **structural simulation will make use of isogeometric analysis; fluid simulation will make use of finite element methods, with appropriate FSI coupling**
  - **SHM system testbed comprised of ultrasonic sensor arrays and infrared thermographic imaging and a full-scale wind turbine blade with in-build structural defects**
  - **ability to dynamically update the simulation model with damage data and enable the prediction of the remaining fatigue life of the structure**
  - **(presently) GPU implementation for near-real-time performance**



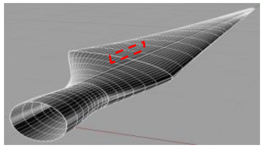
Sandia blade: Rhino 3D



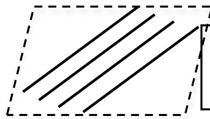


Computational Workflow Diagram

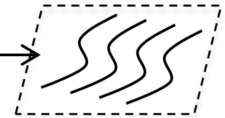
SHM



Sensor data



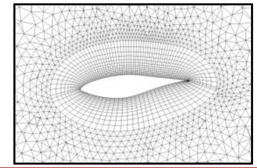
Damage assessment

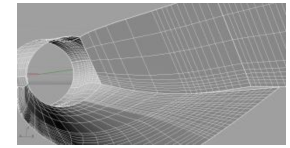


Original composite fiber direction

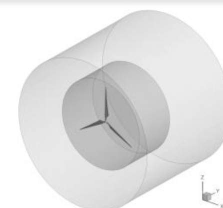
New composite fiber direction

Damage assessment code:
(in house code for sensor data processing and conversion)
Desktop/Single node on HPC cluster
Passive sensors: ~sec - mins
Active sensors: ~mins - hours



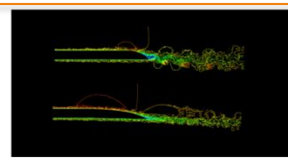


Grid generation code:
Rhino 3D (structural geometry & mesh),
ANSA (fluid mesh),
ParMETIS (decomposition)
Desktop/Large memory HPC node
Structural (re)mesh: ~secs
Fluid mesh (existing template): ~mins
Parallel decomposition: ~mins



FSI code:
Parallel scalable MPI code:
Structural simulation w/ IGA
(adaptive SHM ~mins; can speed-up)
Fluid simulation + FEM FSI coupling
~hours on multicore HPC system
(can speed-up w thin-layer approx'n)

Output:
blade deflection,
vibration freq
…



Sensitivity analysis, optimization, control codes:
Ensemble runs (launched in parallel) using stochastic collocation method, & surrogate management framework
~hours – day on multicore HPC system
Scalable at each step w/ multiple simultaneous FSI runs

Normal operation
or
feedback to adjust operation

Dynamic Data-Driven Methods for Self-Aware Aerospace Vehicles

D. Allaire, K. Willcox (MIT); G. Biros, O. Ghattas (UT Austin); J. Chambers, D. Kordonowy (Aurora)

- Create capabilities for **self-aware aerospace vehicles**
  where each vehicle can dynamically adapt the way it performs missions
  gathering information about itself and its surroundings,
  responding intelligently

- **Approach and objectives**
  - **infer** vehicle health and state through dynamic integration of sensed data, prior information and simulation models
  - **predict** flight limits through updated estimates using adaptive simulation models
  - **re-plan** mission with updated flight limits and health-awareness based on sensed environmental data
- **Methodologies**
  - statistical inference for dynamic vehicle state estimation, using machine learning and reduced-order modeling
  - adaptive reduced-order models for vehicle flight limit prediction using dynamic data
  - on-line management of multi-fidelity models and sensor data, using variance-based sensitivity analysis
  - quantify the reliability, maneuverability and survivability benefits of a self-aware UAV

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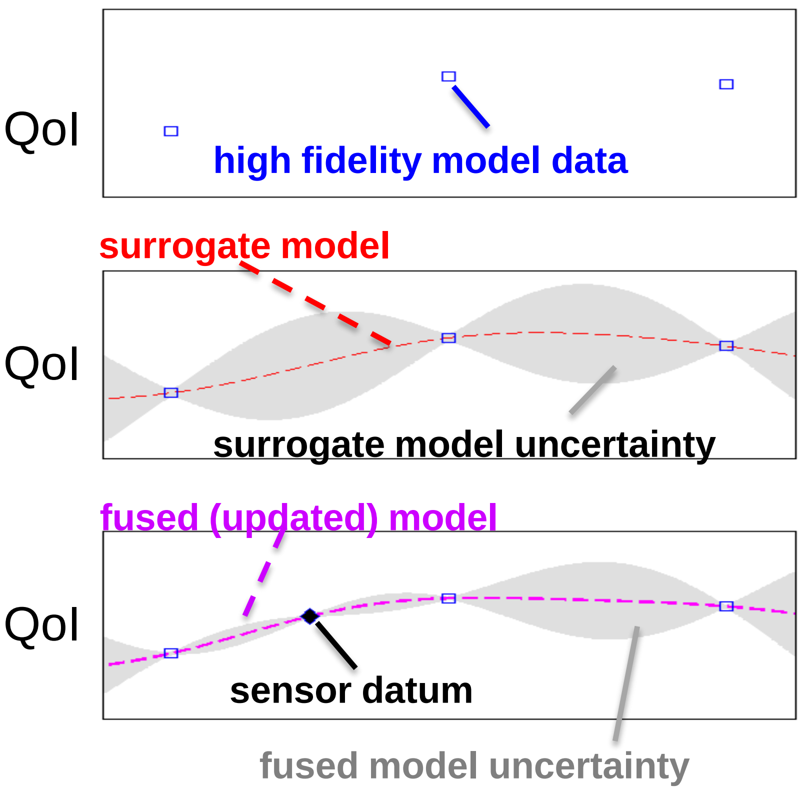
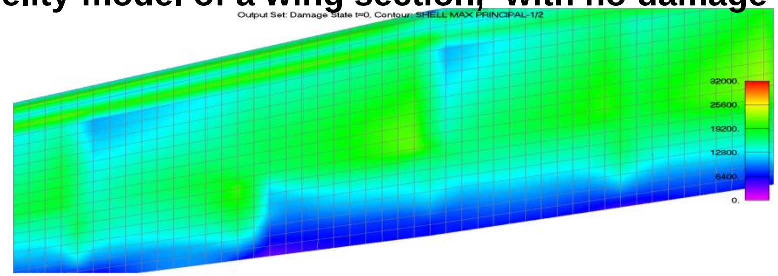
Data Incorporation Examples

Surrogate Models

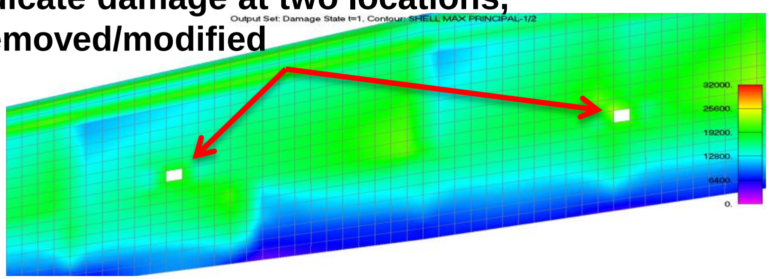


Structural Damage Models

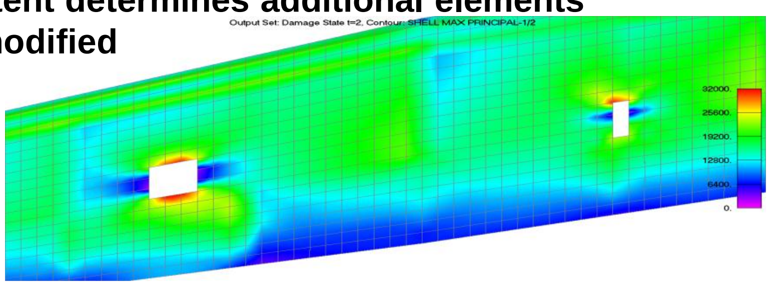
Medium-fidelity model of a wing section, with no damage



Sensors indicate damage at two locations, elements removed/modified



Damage extent determines additional elements Removed/modified



Dynamic Data-Driven Methods for Self-Aware Aerospace Vehicles

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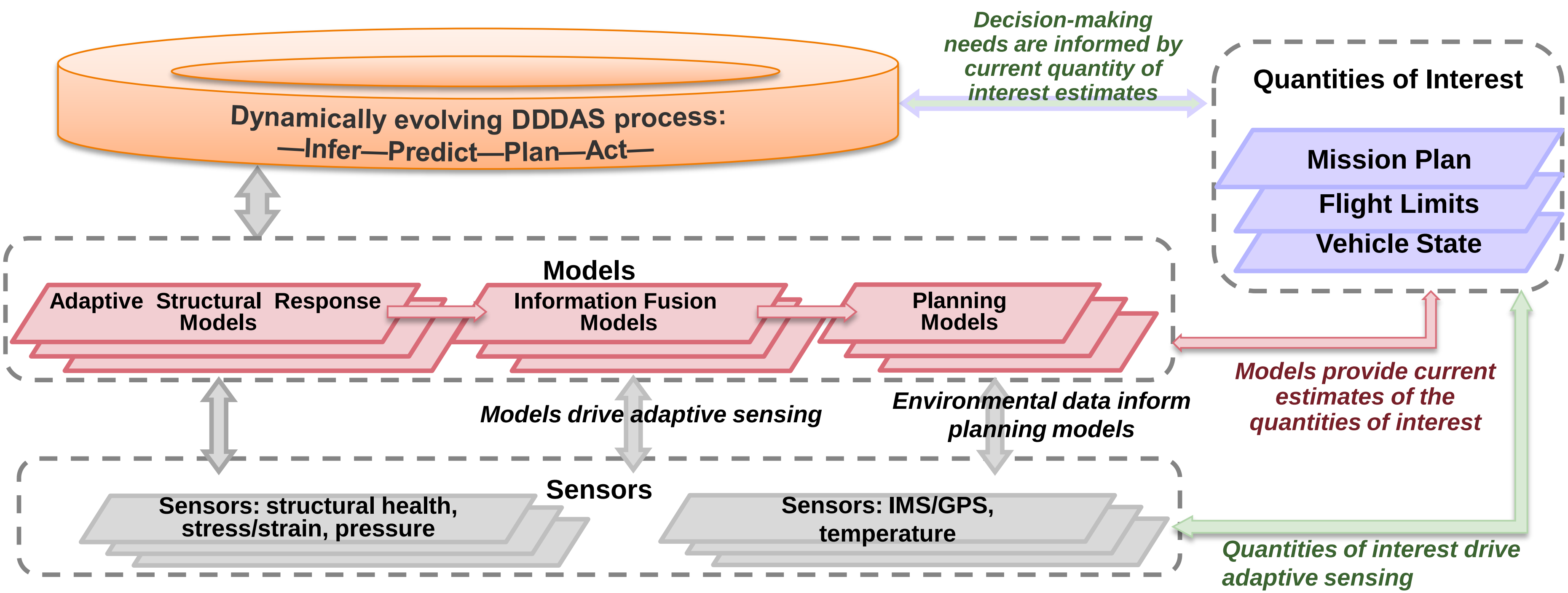


INFERENCE

- Confident estimation of vehicle state in offline phase, time-sensitive estimation of vehicle state in online phase
- Onboard damage model updated using sensed structural data/state
- Efficient algorithms scale well on GPU and manycore architectures

PREDICTION

- Update estimates of flight limits via adaptive reduced-order models
- Progressively fuse higher fidelity information with current information as more time and resources become available
- Sensitivity analysis for dynamic online management of multifidelity models & sensors for vehicle state & flight limit

PLANNING

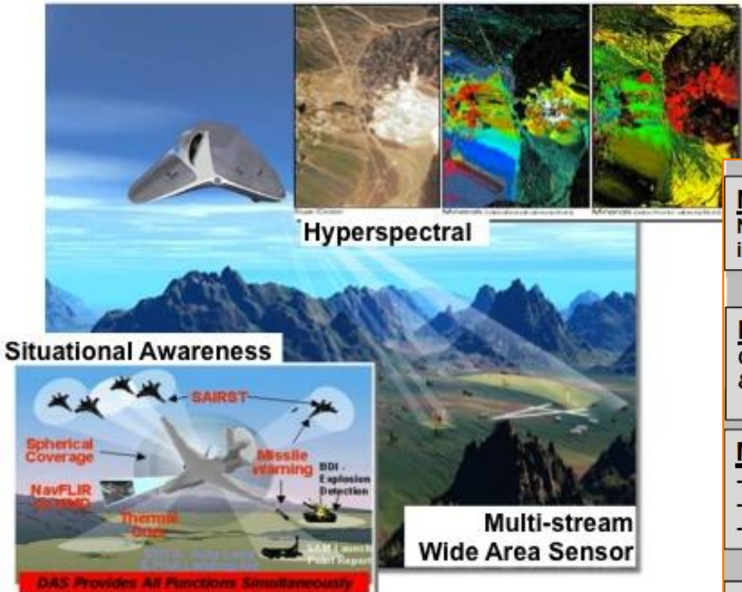
Dynamic environmental data inform online adaption of reduced-order models for mission planning
Multifidelity planning approaches using reduced-order models
Quantification of reliability, maneuverability, survivability

Application of DDDAS Principles to Command, Control and Mission Planning for UAV Swarms

M.B. Blake, G. Madey, C. Poellabauer – U. Of Notre Dame

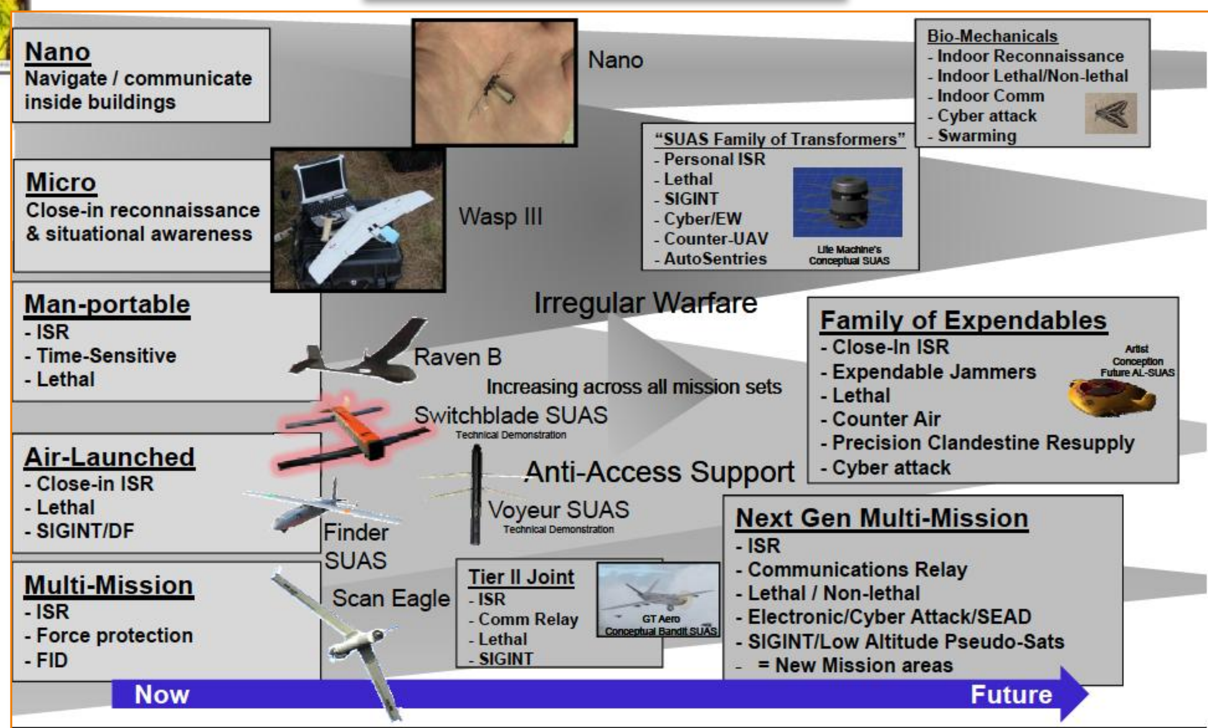
Advancing ISR Capabilities

Intelligence, Surveillance, Reconnaissance
Situational Awareness
Wide Area Airborne Surveillance (WAAS)



Heterogeneity: Micro and Nano-sized Vehicles, Medium "fighter sized" Vehicles, Large "tanker sized" Vehicles, and Special Vehicles with Unique Capabilities

Family of Systems



Lt. Gen. Deptula, 2010

Complex UAV Missions

- Cooperative Sensing
    - HUMINT
    - SIGINT
- Mixed Platforms / Capabilities
- Cooperation with Air and Ground Forces
- Dynamic Adaptive Workflows
- Adaptive Sensing, Computation, Communications

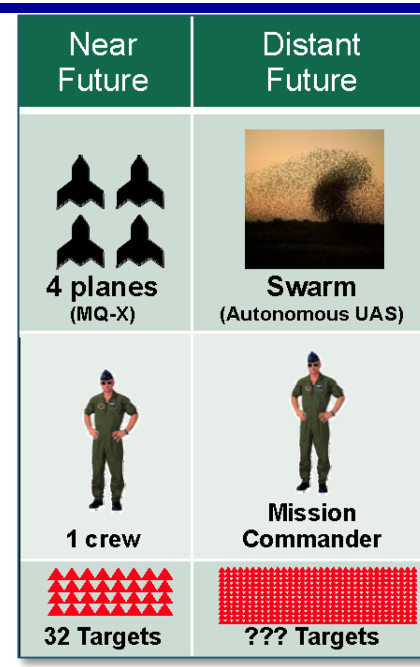
Application of DDDAS Principles to Command, Control and Mission Planning for UAV Swarms

Increasing Operator Load – pilot and sensor operators may need to control “the swarm” not just one UAV

More Complex Missions – cooperate with other aircraft, ground resources, heterogeneous mix of UAVs

Dynamic Mission Re-Planning – surveillance, search & rescue, damage assessment

Resource Constraints – bandwidth, storage, processing, and energy



Maj. Gen. Hansen, 2009

DDDAS Simulation Test-bed

AFRL UAV Swarm Simulator – Dynamic Data Source

Agent-Based DDDAS Simulation – Dynamically Updated Application

Dynamic Adaptive Workflow – DDDAS System Software

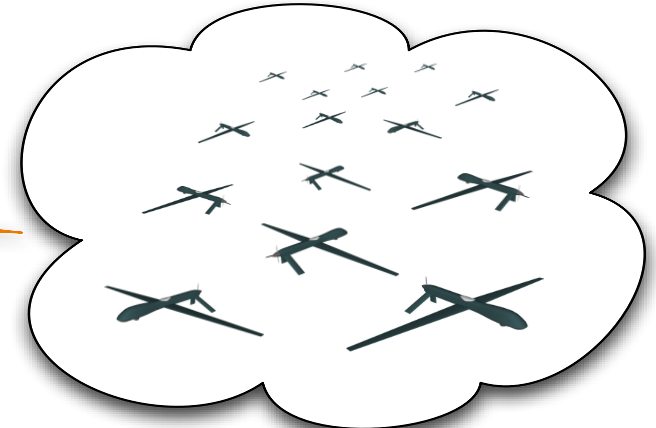
Mission Performance – Global & Local Metrics Optimization

Application of DDDAS Principles to Command, Control and Mission Planning for UAV Swarms

Ground Station

Operator Team
Mission Planning & Re-Planning
Command & Control

UAV SWARM



Application of DDDAS Principles to Command, Control and Mission Planning for UAV Swarms Research Test-Bed

Agent-Based Simulator		UAV Swarm Simulator
Agent-Based Simulator Java/RePast/MASON **Abstract Simulation of Air Vehicles, Interaction with Environment and other Vehicles, and other Agents** **Dynamically Updated Application**	Control Parameters → **System Software QoS Service Composition** ← Real-Time Sensor Feedback	**UAV Swarm Simulator MultiUAV2 - AFRL/RBCA** **6DOF Simulation of Air Vehicles Tactical Maneuvering, Sensor, Target, Cooperation, Route, and Weapons** **Sensor & Air Vehicle Performance**
DDDAS Simulation of UAV Swarm		Synthetic UAV Swarm

How to ensure correctness and consistency in simulation that is dynamically updated?

Challenges / Possible Solutions

How to ensure correctness and completeness of dynamically updated workflows?

Atomic execution/rollbacks? Deadlock detection? Two phase commits? Checkin/checkout? Parallel execution paths?

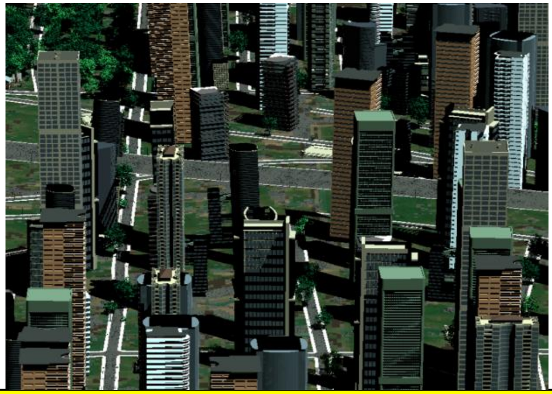
DDDAS for Object Tracking in Complex and Dynamic Environments (DOTCODE)

Anthony Vodacek, John Kerekes, Matthew Hoffman (RPI)

- Create capabilities to ***enhance remote object tracking*** *in difficult imaging situations where single imaging modality is in general insufficient*

- **Approach and objectives**
  - *Use the DDDAS concept of model feedback to the sensor which then adapts the sensing modality*
  - *Employ an adaptive multi-modal sensor in a simulation study*

- **Methodology**
  - Simulation study will leverage existing high spatial resolution Digital Imaging and Remote Sensing Image Generation (DIRSIG) scenes of a cluttered urban area and a desert industrial complex

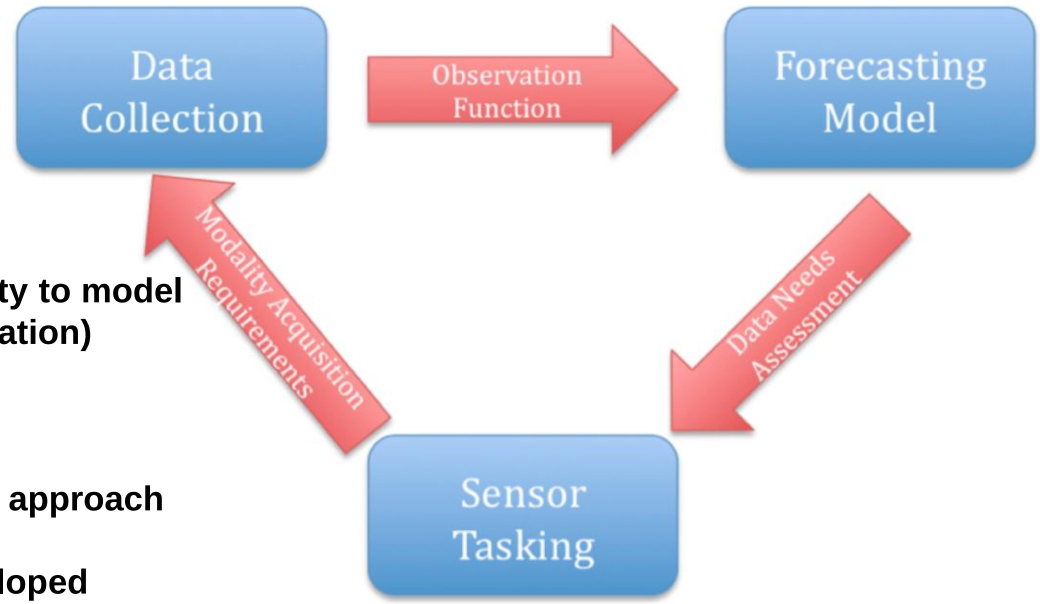


DIRSIG: desert industrial complex

DIRSIG: obscurations and shadows

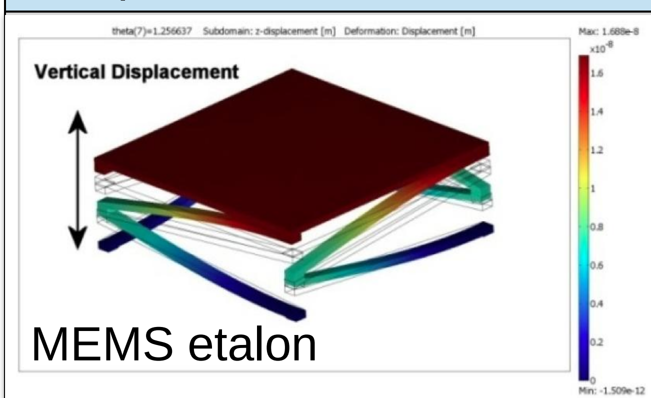
DDDAS for Object Tracking in Complex and Dynamic Environments (DOTCODE)

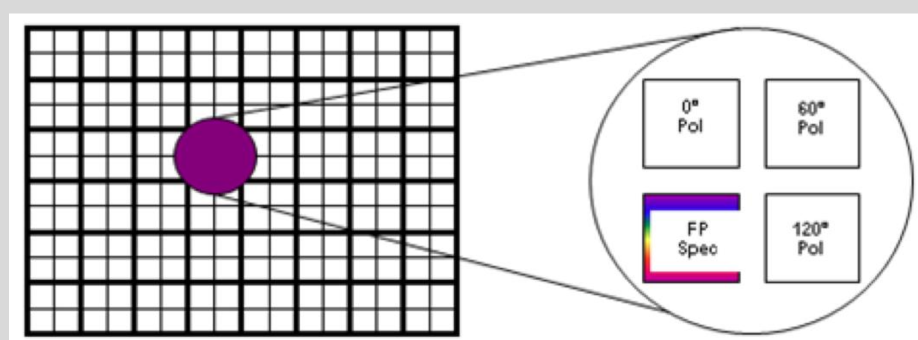
Anthony Vodacek , John Kerekes, Matthew Hoffman (RPI)



- **Research will leverage existing DIRSIG capability to model an adaptive multimodal sensor (HSI and polarization)**
- **DIRSIG animations of moving objects**
- **Object tracking will be done using particle filter approach**
- **Adaptive image processing routines to be developed**

HSI/polarization sensor concept	**The multi-modal sensor - hyperspectral imaging (HIS) and polarization is under development with AFOSR funding**



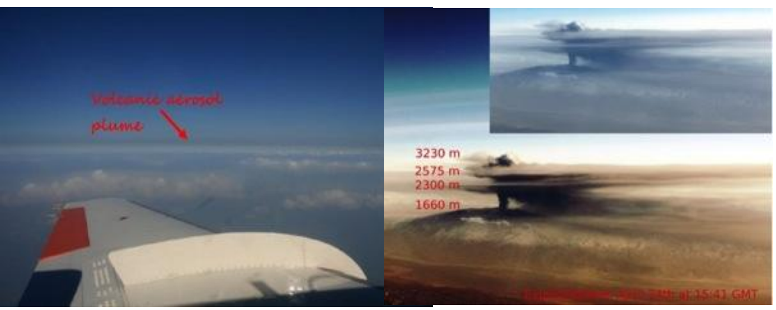


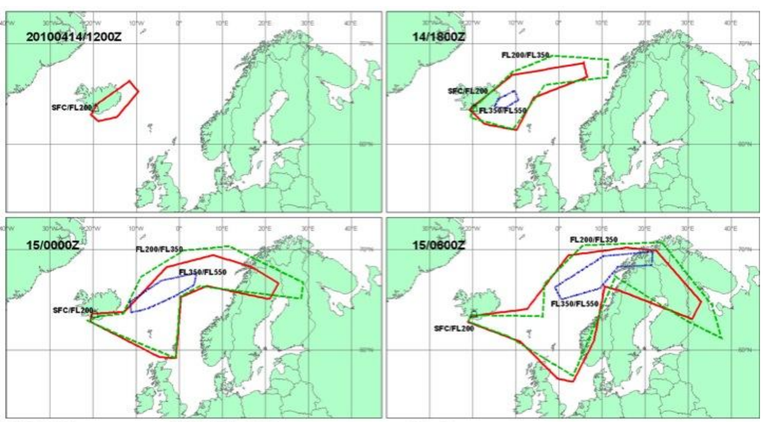
Super pixel concept with etalon and polarization

DDDAS Approach To Volcanic Ash Transport & Dispersal Forecast

A. Patra, M. Bursik, E. B. Pitman, P. Singla, T. Singh, M. Jones – Univ at Buffalo; M. Pavolonis Univ. Wisconsin/NOAA;
B. P. Webley, J. Dehn – Univ Alaska Fairbanks; A. Sandu Virginia Tech

Problem: Currently used forecasts of ash transport in eruption of Eyjafjallajokull, Iceland caused total shutdown of large swathes of airspace, cancellation of more than 100,000 flights and total disruption! Significant discrepancy between no-fly zones, actual ash observation, and multiple model forecasts!





VA ADVISORY
DTG: 20100414/1200Z
VAAC: LONDON
VOLCANO:
EYJAFJALLAJOKULL
PSN: N6338 W01937
AREA: ICELAND

SUMMIT ELEV: 1666M
ADVISORY NR: 2010/001
INFO SOURCE: ICELAND MET OFFICE
AVIATION COLOUR CODE: UNKNOWN
ERUPTION DETAILS: PLUME FROM VOLCANO
REPORTED TO BE UP TO 6000M

RMK: NIL
NXT ADVISORY: 20100414/1800Z

Solution: *Provide **probabilistic map** that can be updated dynamically with observations using a DDDAS approach*

Challenges: Uncertainty Analysis; High fidelity models representing the complex physics capable of needed near real time execution; Data and Workflow Management; Sensor error; measurement mismatch; imagery analysis

Opportunities: Platform for developing DDDAS;
Support optimal flight planning; Timely and accurate hazard analysis preserves life and property

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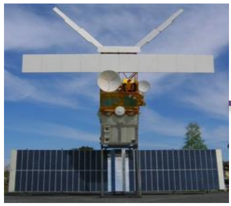
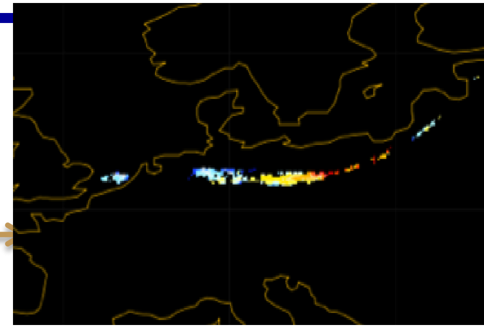
B. P. Webley, J. Dehn – Univ Alaska Fairbanks; A. Sandu Virginia Tech

CALIPSO/SEVIRI

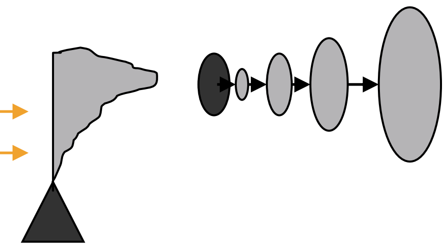


Satellite Image

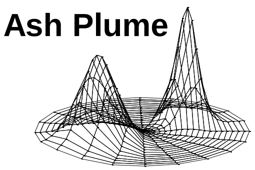
Bayes



pdf Satellite Ash loading/footprint



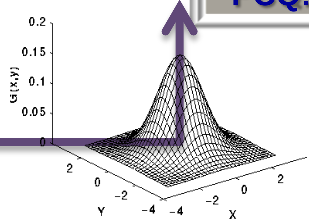
pdf of Ash Plume



+

PCQ: Ensemble BENT-PUFF

-



AGMM

High Fidelity Simulator

Uncertain Wind-Field (Data + NWP)

Source Parameter pdf

Source Parameter ID

BENT: Eruption Plume Model
PUFF: Ash transport and Dispersal Model
PCQ: Polynomial Chaos Quadrature
AGMM: Adaptive Gaussian Mixtures
CALIPSO/SEVIRI: Satellite based sensors for ash detection

Inter-Agency Involvement

- **DDDAS/InfoSymbiotics Multi-agency Workshop (August 2010)**
  - **AFSOR – NSF co-sponsored**
  - **Report posted at www.dddas.org (academic community website)**

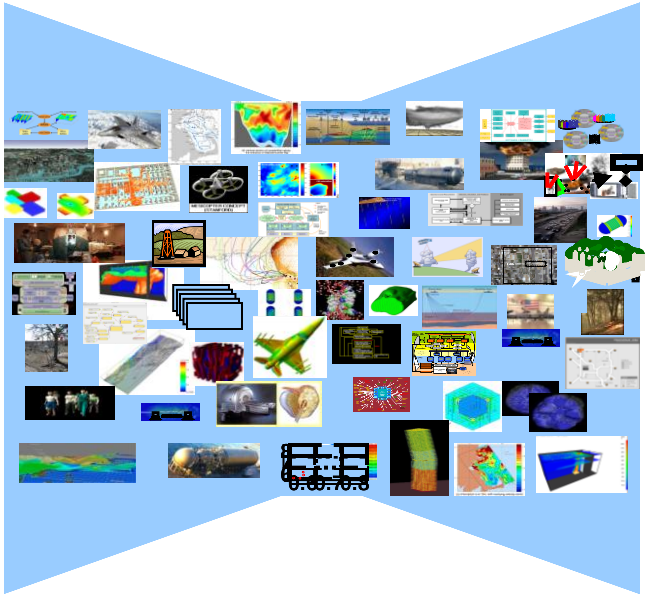
Cross-Agencies Committee

DOD/AFOSR:
F. Darema
R. Bonneau
F. Fahroo
K. Reinhardt
D. Stargel
DOD/ONR: Ralph Wachter
DOD/ARL/CIS: Ananthram Swami
DOD/DTRA: Kiki Ikossi

NASA: Michael Seablom

NSF:
H. E. Seidel (MPS)
J. Cherniavsky (EHR)
T. Henderson (CISE)
L. Jameson (MPS)
G. Maracas (ENG)
G. Allen (OCI)

NIH:
Milt Corn (NLM),
Peter Lyster (NIGMS)



Outreach

Invited Presentations

- (Keynote - SC11 Masterworks) Unification of the High-End Computing with the Real-Time Data Acquisition and Control; SC11, Seattle WA, Nov 16, 2011
- (Keynote) InfoSymbiotics/DDDAS – Why Now More than Ever; Workshop on Modeling and Sensing Environmental Systems; LNCC-Petropolis, Brazil, August 8-11, 2011
- (Lecture) InfoSymbiotics – The power of Dynamic Data Driven Applications Systems (DDDAS), Los Alamos National Lab, May 24, 2011;
- (Invited Lecture) InfoSymbiotics – The power of Dynamic Data Driven Applications Systems (DDDAS), Morgridge Institute – Wisconsin Institutes of Discovery, April 28, 2011
- (Keynote) Transformative Research &Technology Directions in the context of Transformative Partnerships, UIUC Innovation Summit, April 13, 2011
- (Keynote) Unification Paradigms in the Dynamics of Information Systems, DIS2011, February 17, 2011
- (Talk) AFOSR Overview (& Vision and Strategy for the RSL Directorate), NCSU Faculty Day, February 1, 2011
- (Distinguished Lecture) DDDAS and Vision and Strategy for the RSL Directorate, UT/Austin, January 26, 2011
- and… over a dozen other invited keynotes/talks since the Aug 2010 Workshop to the end of 2010

AFRL

- (Talk) InfoSymbiotics – The power of Dynamic Data Driven Applications Systems (DDDAS), Kirtland AFB, May 25, 2011

Workshop/PI-Meeting (Planned)

- DDDAS Workshop in conjunction with ICCS2012 (Internat'l Conf. on Comput'l Sciences) – June2012

Recognition

- IEEE Technical Achievement Award (May 2011)

Other Programmatic Interactions

Transition Activities

- **Volcanic Ash Propagation Modeling – interest/interactions with AF/MC (Erbschloe) and AFRL/RZ (Rivir)**
- **Multi-UAV Agent-Based simulation – PI contact with AFRL/RB (Rasmussen) and AFIT (….)**
- **DOTCODE – in coordination with project funded by Kitt Reinhardt(RSE)**

Research trends

- **Scope of other projects started:**
  - **systems software research seamlessly the dynamic integration and interaction of simulation-computations with sensor data acquisition/processing/actuation and enforcing required guarantees on task performance (active-data, data-structures, and cross-systems adaptive interface methods for computational efficiency)**
- **Scope of proposals expected:**
  - **Polyhedral approaches in runtime/compilers for adaptive mapping and optimized execution exploiting heterogeneous and distributed computational and instrumentation resources**
  - **Stochastic Control methods for Multi-sensor/Multi-UAV control and target tracking**
  - **Machine perception and learning mathematical and statistical methods for evaluating *contextual information value* of emerging on-line data**
  - **Methods for real-time knowledge extraction and classification for resource constrained heterogeneous processing**
  - **Adaptive Agent-based multi-scale simulations for urban surveillance with scalable and robust anomaly-detection methods, endowed with noise-filtering, fidelity control, and optimized resource utilization**

Interactions with other agencies

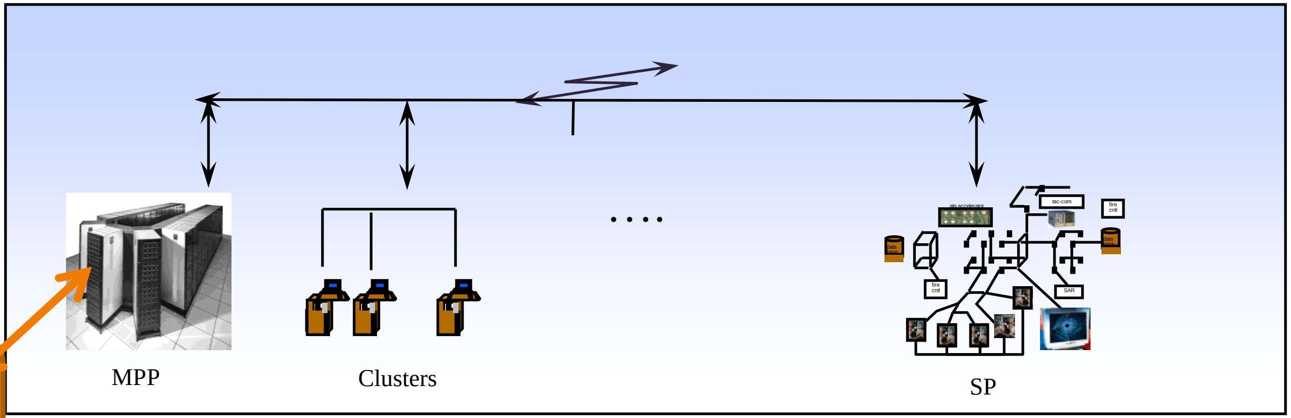
- **Expect to build-upon established colalborations**

back-ups

A while back we talked about Computational Grids…

Heterogeneity within and across Platforms

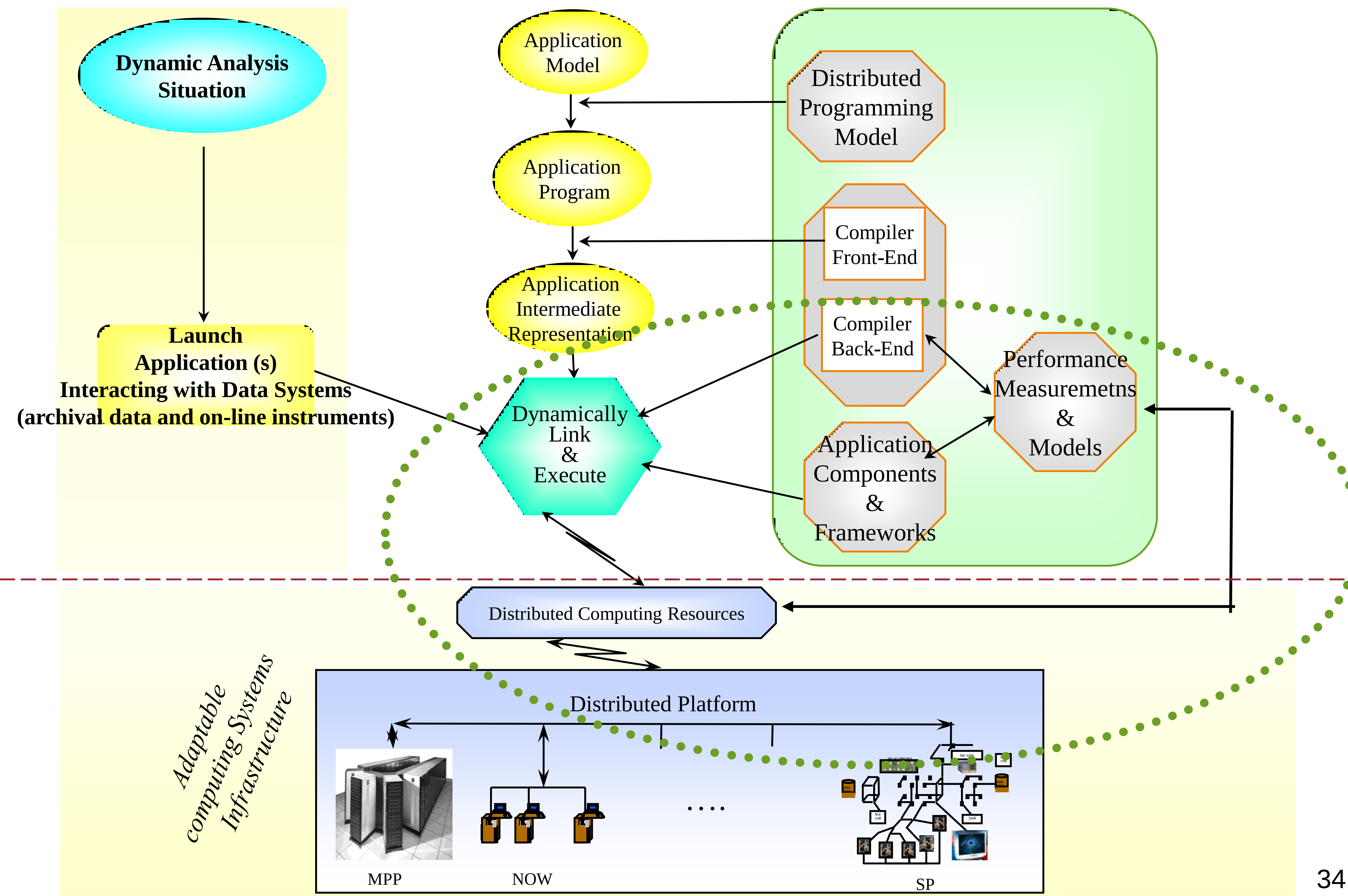
- Multiple levels of hierarchies of processing nodes, memories, interconnects, latencies



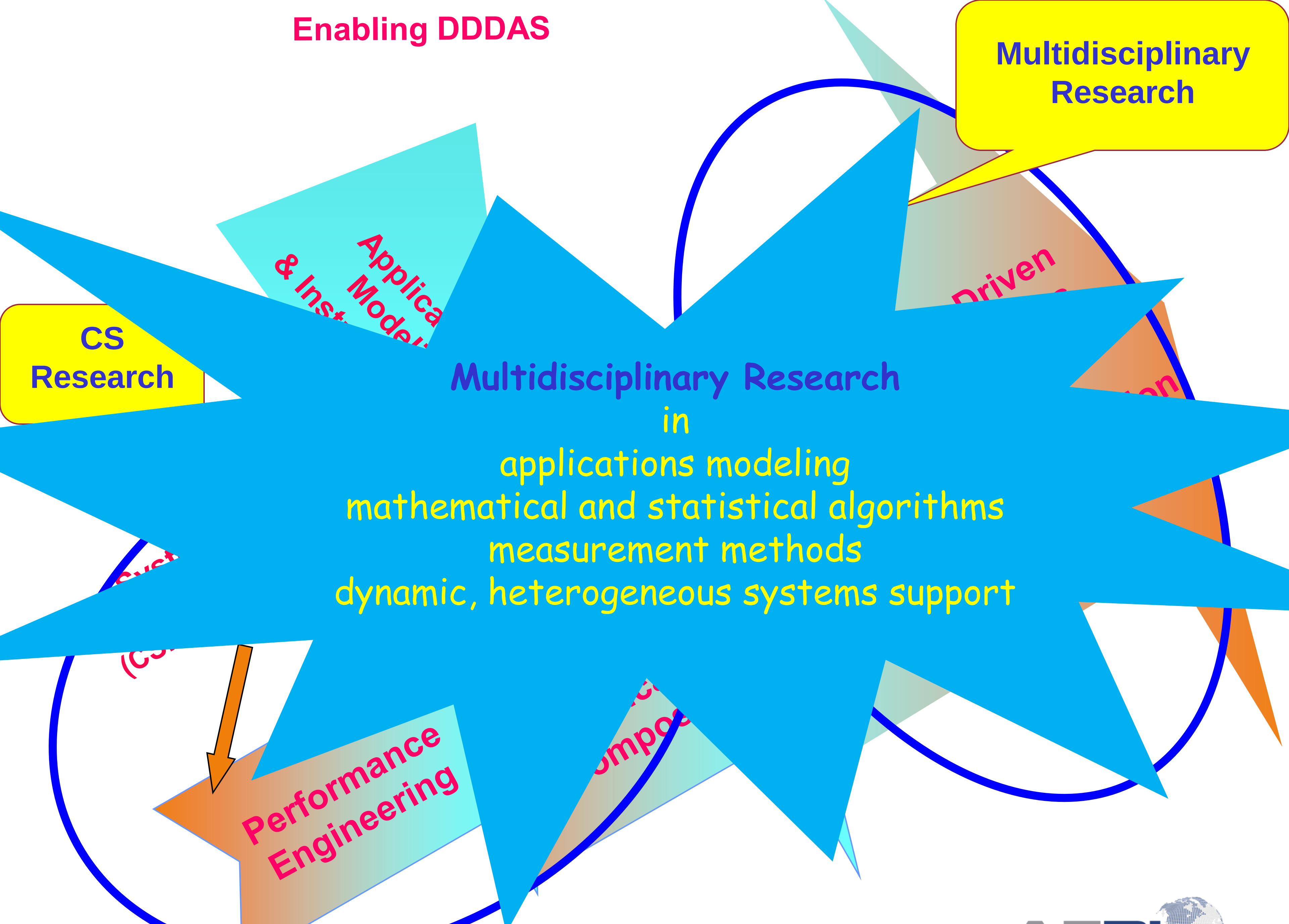
High-End: Grids-in-a-Box (GiBs)

Grids: Adaptable Heterogeneous Computing Systems Infrastructure

Dynamic Runtime Support (NSF/NGS Program '98-'04; '05-'07)
Runtime Compiling System (RCS) and Dynamic Application Composition



Enabling DDDAS

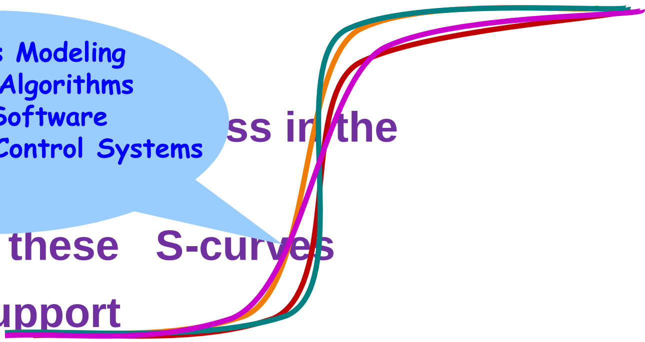


Where we are … & QUO VADIMUS

- **DDDAS/InfoSymbiotics**
  - high pay-off in terms of new capabilities
  - need fundamental and novel advances in several disciplines
  - research agenda comprehensively defined
- **Progress has been made – it’s a “multiple S-cur**

  Applications Modeling
  Math&Stat Algorithms
  Systems Software
  Instrumentation/Control Systems

  - experience/advances cumulate to accelera ss in the future
  - we have started to climb the upwards slope of each of these S-curves
  - reinforce need for sustained, concerted, synergistic support



- **Workshop and Report (August 30&31, 2010)**
  - DDDAS/InfoSymbiotics broad impact - Multi-agency interest
  - can capitalize on past/present progress through projects started
  - timely in the landscape of: ubiquitous sensoring/instrumentation, big-data, multicore-based high-performance systems, multi modeling, uncertainty quantificati
  - the present landscape enriches the research agenda and opp

In 2002 DDDAS provided the initial funding for the Generalized Polynomial Chaos work (Karniadakis and Xiu)

Damage Modeling

Development of a Stochastic Dynamic Data-Driven System for Prediction of Material Damage

J.T. Oden (PI), P. Bauman, E. Prudencio, S. Prudhomme, K. Ravi-Chandar – UTAustin

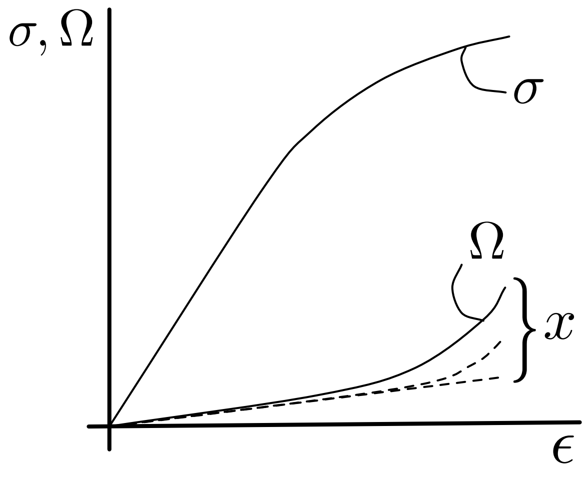
Experimental Damage Generation and Detection

- **Inverse problem to find resistance and relate to material damage.**

$\Omega(x) =$ Resistance

$$\nabla^2 \phi = 0$$

$$\nabla \phi = E = \Omega(x) j(x)$$



- No limitation on frequency of measurements (quasi-static).
- Damage of the sensors are the measurements.
  - Degradation of measurements over time.

Micromechanical Damage Model

$W =$ Strain-work, sum of elastic and dissipative parts

$$W(\epsilon, d) = W_e(\epsilon; d) + W_d(d)$$

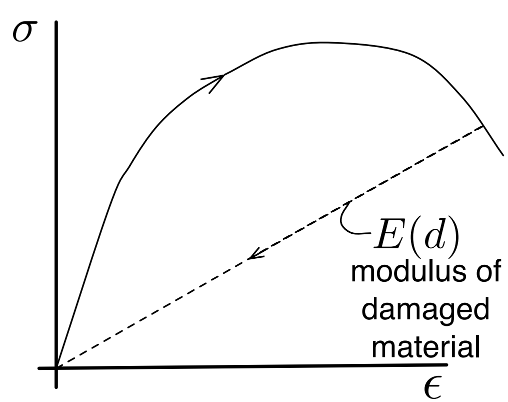
$\epsilon =$ strain

$d = d(\Omega) =$ damage

$$\sigma = \frac{\partial W}{\partial \epsilon}$$ elastic response

$$\frac{\partial W}{\partial d} \geq 0$$ damage must remain constant or increase (no healing)

$$\left(\frac{\partial W_e}{\partial d} + \frac{\partial W_d}{\partial d} \right) \dot{d} = 0$$



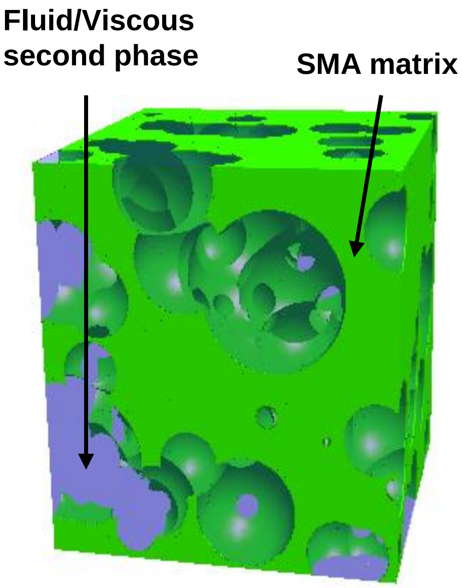
Dynamic Data-Driven Modeling of Uncertainties and 3D Effects of Porous Shape Memory Alloys

Craig Douglas (U. of Wyoming); Yalchin Efendiev and Peter Popov (TAMU)

- New Capabilities:
  Design of **vibration isolation devices** using **porous Shape Memory Alloys**

- Approach and Objectives:
  - Consider porous SMAs:
    - **similar macroscopic behavior but mass/weight is less, and thus attractive for aerospace applications**
    - **similar macroscopic hysteretic response as their dense counterparts**
  - Develop Multiscale Model of porous SMAs utilizing iterative homogenization
  - Incorporate a viscous phase in the pore space, which allows additional tuning of vibration isolation characteristics

- Methodology:
  - The numerical scheme used (iterative MsFEM) integrates the fine scale (porous microstructure) into the coarse scale (homogenized SMA material + vibration isolation device)
  - the MsFEM will be incorporated into a global solver which simulate a porous SMA on a shaker device
  - The coarse solver thus depends on a large number of nonlinear cell problems; **solved on a cluster – massively parallel multicore-based system**, to speed-up the MsFEM



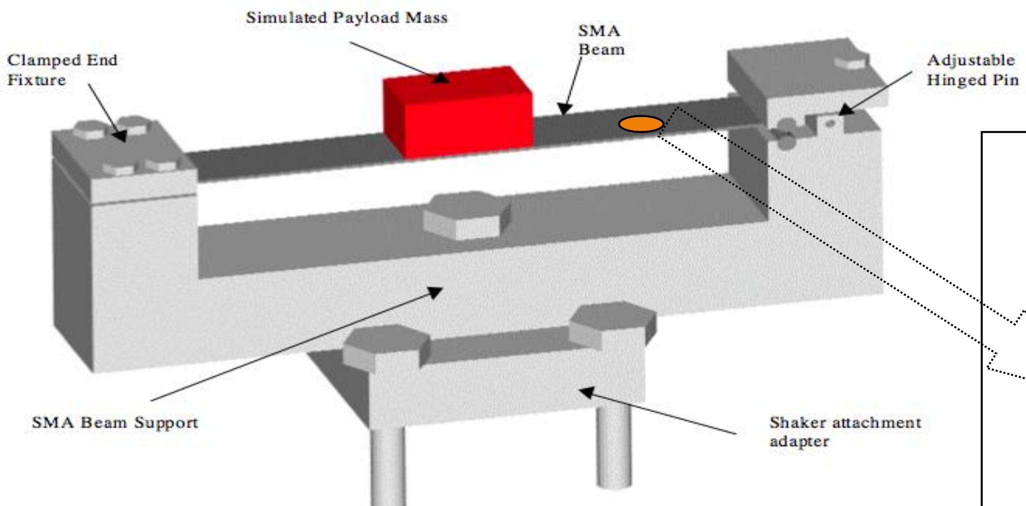
Sample unit cell of porous SMA with random microstructure and fluid/viscous second phase.

Dynamic Data-Driven Modeling of Uncertainties and 3D Effects of Porous Shape Memory Alloys

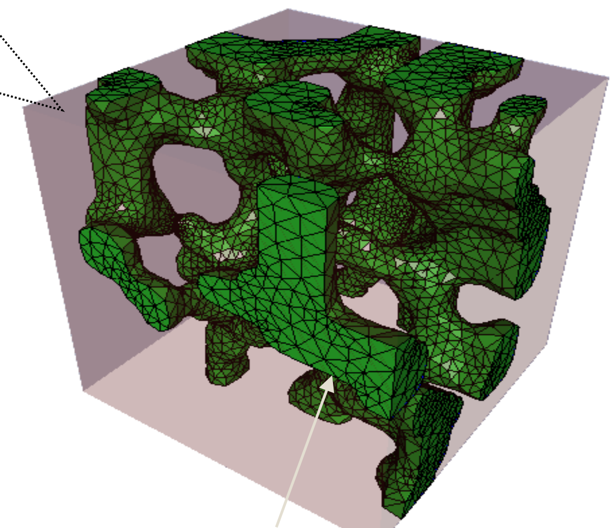
Craig Douglas (U. of Wyoming); Yalchin Efendiev and Peter Popov (TAMU)

Virtual Shaker Setup

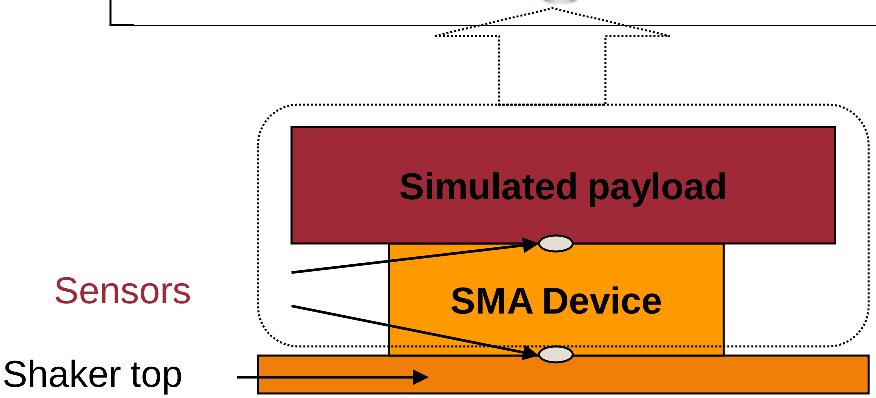
Forward FEM Model simulates the loading of the payload/SMA device configuration



MsFEM provides effective material response at selected locations



Fine scale FEM discretization and mesh



DDDAS Approach To Volcanic Ash Transport & Dispersal Forecast

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Interim Progress:

- **Developed parallelized PCQ/Bent-Puff HPC based tool for probabilistic ash forecasting**
- **Physics based methodology for VATD "transport and dispersion" model inputs –**
  poorly characterized column height, mass eruption rate replaced by pdf of observable vent parameters and speed.
- **PCQ based probabilistic hazard analysis replaces predictions of existing tools.**
- **Results for Eyjafjallojokull are very promising –**
  all ash observed was inside a Probability>0.2 contour with most in Probability >0.7
- **Presently, this is the only risk-based (probabilistic) forecast for ash cloud with full transport modeling**